Kanalku Lake Subsistence Sockeye Salmon Project: 2011 Annual Report

by

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Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

The sockeye salmon (*Oncorhynchus nerka*) run at Kanalku Lake, Southeast Alaska, has provided the preferred traditional subsistence sockeye salmon stock for the people of Angoon for generations. A stock assessment program at Kanalku Lake began in 2001 in response to community concerns over declining run size and possible overexploitation by local fishermen. Mark-recapture studies were conducted between 2001 and 2006 to estimate the spawning escapement. To add confidence to the escapement estimates, an adult counting weir was added to the project in 2007 and weir operation was continued through present. In 2011, the best estimate of escapement was the weir count of 728 sockeye salmon, which was validated with a weir-to-spawning-grounds mark-recapture estimate of 690 sockeye salmon (95% CI 600–800). In most years the escapement is dominated by age-1.2 sockeye salmon. In 2011, however, there were nearly as many age-1.3 fish in the escapement (46.0%) as age-1.2 fish (49.4%) fish due to a small return of age 1.2 fish from a poor 2007 parent-year escapement. Reported subsistence harvest of sockeye salmon at Kanalku Bay in 2011 was 419 fish.

Key words: sockeye salmon, *Oncorhynchus nerka*, subsistence, Kanalku Lake, escapement, weir, mark-recapture, age composition, Southeast Alaska.

INTRODUCTION

The coastal village of Angoon, Alaska, located on the western side of Admiralty Island, has a long history of utilizing sockeye salmon (*Oncorhynchus nerka*) from the Kanalku Lake drainage. The use of Kanalku Bay as a traditional subsistence fishery has been documented in several historical and archaeological records, and artifacts from a traditional salmon weir at the head of Kanalku Bay provides physical evidence of the exploitation of salmon resources for at least the last 1,000 years (de Laguna 1960; Moss 1989; Thornton et al. 1990; Goldschmidt and Haas 1998). Although other sockeye salmon runs in the vicinity are available for Angoon subsistence fishermen, including Sitkoh and Basket bays (Geiger and ADF&G Staff 2007), Kanalku Bay remains the preferred harvest area due to its close proximity to the village and ease of access through sheltered waterways. After the adoption of Alaska statehood, a non-commercial subsistence fishery was defined and put under a permit system (Turek et al. 2006). Residents of Angoon can obtain subsistence fishing permits for Kanalku, Sitkoh, and Basket bays, along with other nearby areas, but most people prefer to fish in Kanalku Bay (Conitz and Burril 2008).

In the late 1990s, annual reported subsistence harvests at Kanalku Bay increased substantially at the same time abundance of Kanalku Lake sockeye salmon appeared to decline. Although reported subsistence harvest tends to under-represent the true community harvest (Conitz and Cartwright 2003; Lewis and Cartwright 2004; Lorrigan et al. 2004; Walker 2009), the reported harvests are useful for looking at trends in subsistence catch (Geiger and ADF&G Staff 2007). The reported subsistence harvest at Kanalku Bay increased from an average of 580 sockeye salmon in the late 1980s to an average of 1,550 in the late 1990s (Figure 1). Some Angoon residents reported a decline in the overall abundance of Kanalku sockeye salmon in the 1990s and suggested that community members "slow down" in harvesting that stock (Conitz and Cartwright 2005; Conitz and Burril 2008).

The Alaska Department of Fish and Game (ADF&G) initiated a stock assessment program in 2001 in response to the concern about declining run size and the lack of information about spawning escapements (Conitz and Cartwright 2005). From 2001 to 2006, mark-recapture studies were conducted at Kanalku Lake to estimate the spawning population of sockeye salmon. In 2001, the reported subsistence harvest of sockeye salmon at Kanalku Bay far exceeded an alarmingly low mark-recapture estimate of less than 300 spawners at Kanalku Lake (Conitz and Cartwright 2005). The Angoon community and ADF&G fisheries managers agreed by consensus that the community would voluntarily curtail fishing in Kanalku Bay during at least the first half

of the run (defined as through 14 July) for the 2002 season (Conitz and Burril 2008). In addition, harvest limits at other nearby subsistence sockeye salmon fisheries were increased to encourage fishing effort elsewhere and allow the Kanalku stock to rebuild. The voluntary closure was in place from 2002 to 2006, during which the reported harvest of sockeye salmon in Kanalku Bay was minimal. The escapement in 2003 was estimated to be less than 300 sockeye salmon but escapement estimates in 2002 and from 2004 to 2006 averaged about 1,300 fish (Conitz and Cartwright 2005).

The voluntary closure at Kanalku Bay was respected, for the most part, and the regular permitted subsistence fishery was resumed in 2006 with a later fishing season and smaller harvest limit of 15 sockeye salmon per household (Conitz and Burril 2008). The later fishing season made subsistence harvest difficult, so it was subsequently shifted back to an earlier fishing season in 2007. Since the end of the voluntary closure, the reported harvest averaged about 600 sockeye salmon, 2008–2010 (Figure 1).
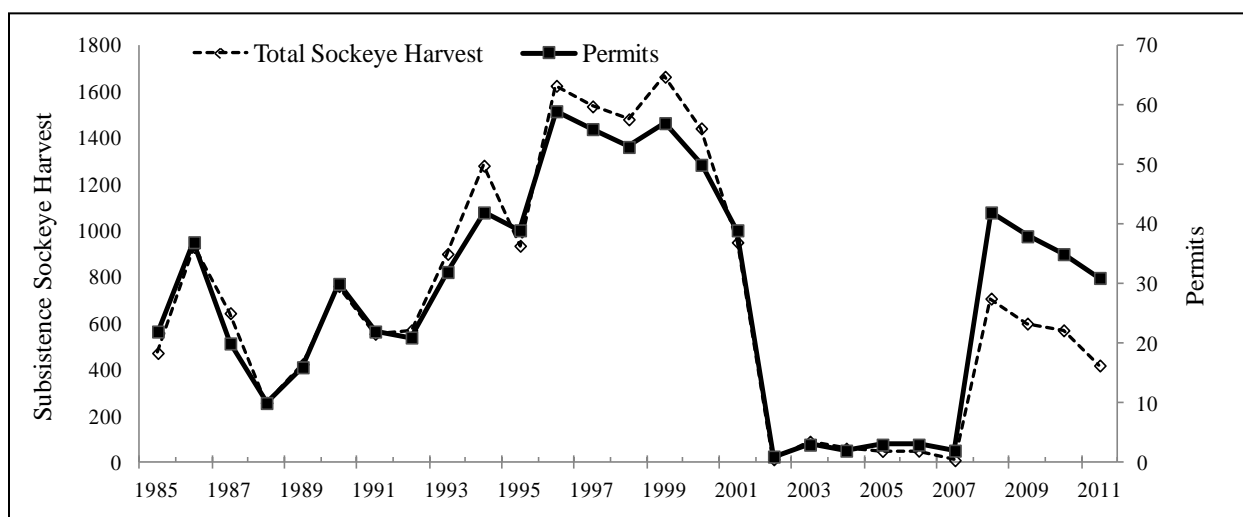
Figure 1.–Reported subsistence harvest of Kanalku sockeye salmon and number of subsistence permits issued, 1985–2011.

Beginning in 2007, ADF&G, in cooperation with the Angoon Community Association, expanded the stock assessment project by installing a sockeye salmon weir directly below the outlet of Kanalku Lake to observe run timing, count the sockeye salmon escapement, and conduct a weir-to-spawning grounds mark-recapture estimate of escapement. Escapements were less than 1,000 fish in both 2007 and 2008, but improved to more than 2,500 sockeye salmon in both 2009 and 2010 (Vinzant et al. 2009–2011; Vinzant and Bednarski 2010).

Kanalku Falls, a partial barrier to sockeye salmon migration in Kanalku Creek, is known to have a major influence on the size of the sockeye salmon escapement at Kanalku Lake. In most years, substantial numbers of sockeye salmon sit in the pools below the falls where they are susceptible to predation and repeatedly batter themselves on the rocks as they attempt to jump the falls and migrate upstream. In 1970, the U.S. Forest Service blasted resting pools and a small channel in the bedrock at the falls to assist migrating salmon (Geiger and ADF&G Staff 2007) but many fish still do not successfully ascend the falls. Our work at the weir, combined with efforts by the U.S. Forest Service, suggests that a larger portion of the sockeye salmon run is able to ascend the falls during periods of low water flow compared to periods of high water flow (Vinzant et al. 2010; Vinzant and Bednarski 2010). In 2008, a year of high precipitation, we estimated that

fewer than half of the sockeye salmon that entered Kanalku Creek successfully ascended Kanalku Falls, whereas in 2009, a year of low precipitation, about 75% of the sockeye salmon were able to pass the falls (Vinzant et al. 2010).

Sockeye salmon escapement at Kanalku Lake may also be affected by nearby commercial fisheries conducted in Chatham Strait where sockeye salmon are harvested incidentally in purse seine fisheries targeting pink salmon (*O. gorbuscha*). Although we have no estimates of the commercial harvest of Kanalku sockeye salmon, management of the Chatham Strait fisheries is based on the assumption that this interception is insignificant because of the early run timing of Kanalku sockeye salmon compared to the timing of fishery openings, the distance of Kanalku Bay from these fisheries, and the nature of the mixed stock area where fishing occurs (Geiger and ADF&G Staff 2007). Based on subsistence harvest data collected since 1985, 87% of the total season's subsistence harvest is completed by the time the first purse seine fishery opens in Upper Chatham, and 97% by the end of July (Geiger and ADF&G Staff 2007). In addition, the area closest to the community of Angoon and Kanalku Inlet has been closed to the purse seine fishery, which includes the Chatham Strait shoreline along an area of approximately nine nautical miles from Parker Point to Point Samuel, west and north of Kootznahoo Inlet.

The primary focus of the sockeye salmon assessment project has been to produce reliable annual estimates of the spawning escapement at Kanalku Lake. In 2011, we counted fish through a picket weir at the outlet of the lake, observed run-timing, collected biological data, and estimated the total escapement of sockeye salmon with a weir-to-spawning grounds mark-recapture study.

OBJECTIVES

1. Count all salmon species passed through the weir to Kanalku Lake for the duration of the sockeye salmon run.
2. Estimate the escapement of sockeye salmon into Kanalku Lake with mark-recapture studies so the estimated coefficient of variation is less than 15%.
3. Estimate the age, length, and sex composition of the Kanalku Lake sockeye salmon escapement.

METHODS

STUDY SITE

Kanalku Lake (lat 57° 29.22'N, long 134° 21.02'W) is located about 20 km southeast of Angoon (Figure 2) and lies in a steep mountainous valley within the Hood-Gambier Bay carbonates ecological subsection (Nowacki et al. 2001). The U-shaped valley and rounded mountainsides are characterized by underlying carbonate bedrock and built up soil layers supporting a highly productive spruce forest, especially over major colluvial and alluvial fans. The watershed area is approximately 32 km^2, with one major inlet stream (ADF&G stream no. 112-67-060) draining into the east end of the lake. The lake elevation is approximately 28 m. The lake surface area is approximately 113 hectares, with mean depth of 15 m, and maximum depth of 22 m (Figure 3). The outlet stream, Kanalku Creek (ADF&G stream no. 112-67-058), is 1.7 km long and drains into the east end of Kanalku Bay. In addition to sockeye salmon spawning in the lake, large numbers of pink salmon (*O. gorbuscha*) spawn in the lower part of the outlet creek and intertidal area. A few coho (*O. kisutch*) and chum (*O. keta*) salmon spawn in the Kanalku system, and resident populations of cutthroat trout (*O. clarkii*), Dolly Varden char (*Salvelinus malma*), and sculpin (*Cottus sp.*) are found in Kanalku Lake. Kanalku Falls, a waterfall approximately 8–10 m high and about 0.8 km upstream from the tidewater, forms a partial barrier to migrating sockeye salmon.

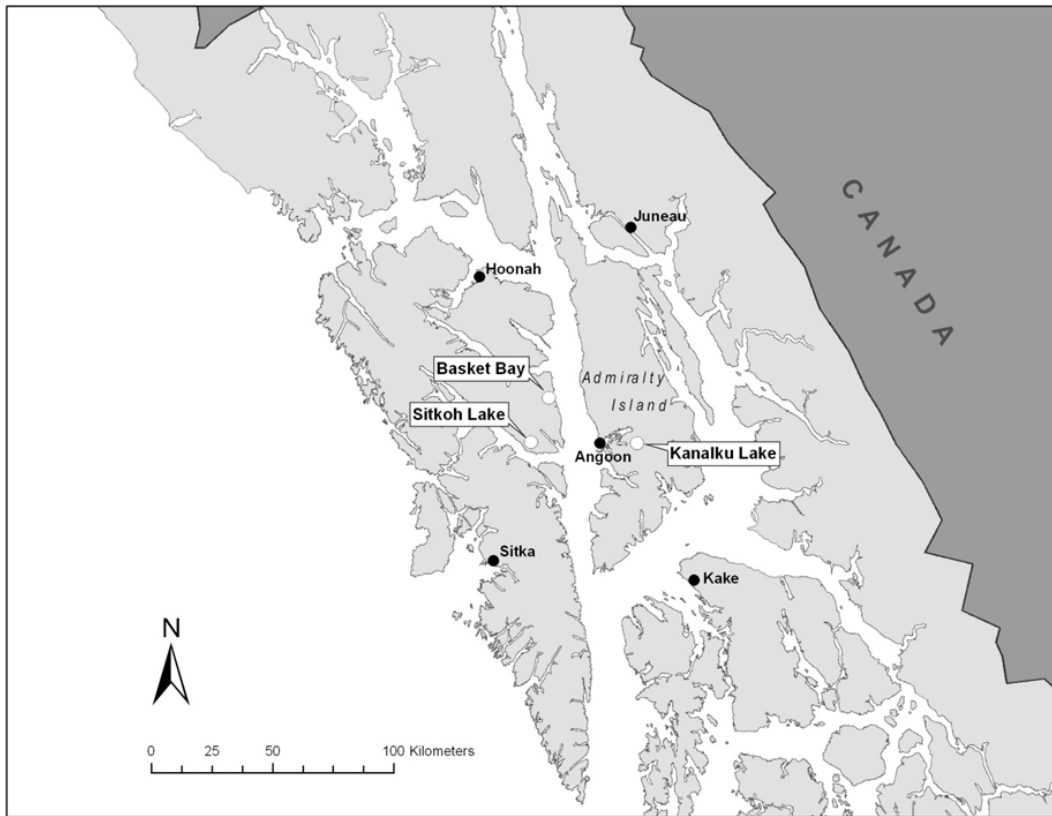Figure 2.–Map of Southeast Alaska showing location of Kanalku Lake and the village of Angoon.
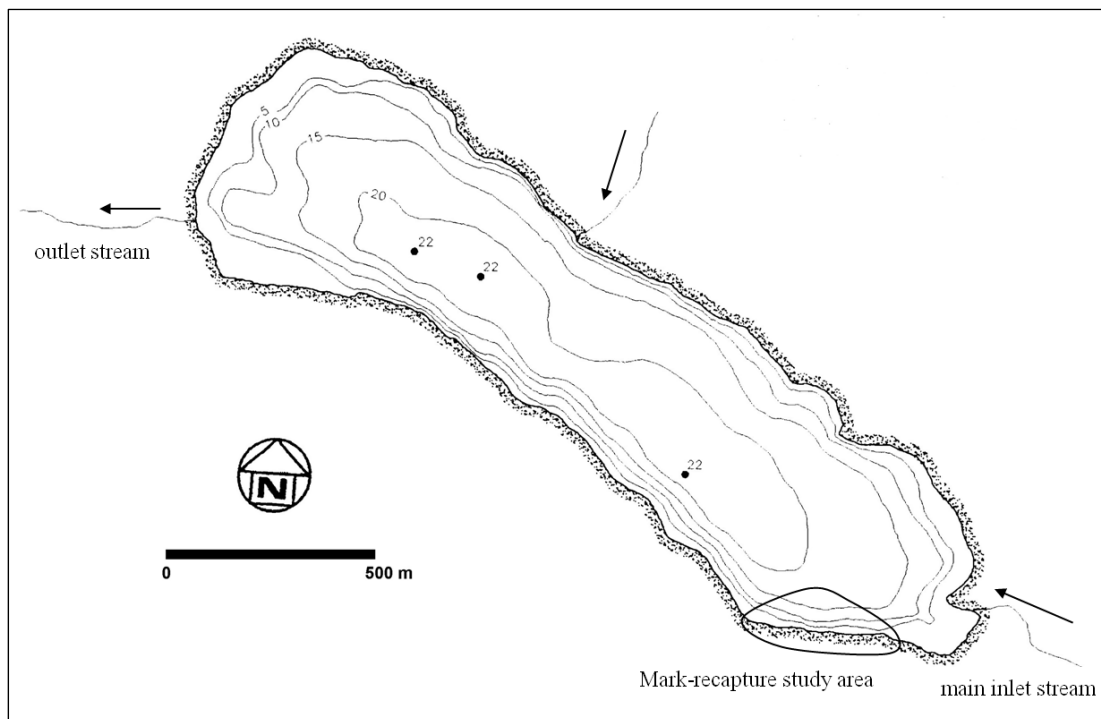

Figure 3.–Bathymetric map of Kanalku Lake, showing 5-m depth contours, and the mark-recapture study area. Arrows indicate direction of stream flow.

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SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The Kanalku weir was located in Kanalku Creek, across the outlet stream at the west side of the lake. The weir consisted of aluminum bipod supports anchored in the stream sediment. The supports were connected by rows of stringers that extended across the entire stream bed, with pickets inserted through regularly-spaced holes in the stringers and extended to the stream bottom. Picket spacing was 1-3/4 inches (4.45 cm) on center of the pickets. This spacing, called "pink salmon spacing," allows for 52 pickets per channel with a maximum space of approximately 1-1/2 inches (3.81 cm) between pickets. Sandbags were placed across the stream along both sides of the weir to help stabilize the substrate and secure the pickets in place. A weir trap, sampling station, and catwalk were constructed and attached to the weir. Technicians inspected the weir daily for malfunction and breaches.

To minimize handling, fish were counted through the weir by pulling one or two pickets at the upstream side of the weir trap. We placed white sandbags on the bottom of the stream bed at this exit point to aid in fish identification. In addition to counting all fish by species, all sockeye salmon were visually categorized as jacks (fish less than 400 mm in length) or full-size adults. Daily observations of the water level, air and water temperature, and weather were recorded at the weir. The weir was in operation from 25 June to 3 September. Water level was measured daily at approximately the same location (within 1 m^2) as the 2007 to 2010 field seasons.

Weir to Spawning Grounds Mark-Recapture Estimate

The total population of sockeye salmon was estimated with a two-event mark-recapture study for a closed population (Seber 1982). The mark-recapture study allowed us to determine if sockeye salmon passed through the weir undetected, and served as a back-up estimate in the case that the weir was breached or damaged. In Event 1, fish were marked at the weir with a combination of an adipose fin clip and either an axillary process clip or dorsal fin clip. Marking at the weir was stratified through time on the following schedule: left axillary process clip from 25 June to 23 July, right axillary process clip from 24 July to 8 August, and dorsal fin clip from 9 August to 29 August. The adipose fin clip facilitated easy identification of marked fish and served as the primary mark. Any fish marked and released with only an adipose fin clip was noted. To minimize handling, fish sampled for age, sex, and length were also marked. The target marking rate was 35% of the weekly sockeye salmon escapement. Sockeye salmon that appeared unhealthy were enumerated and released without marks.

In Event 2, fish were sampled for mark recovery with a beach seine in the only major spawning area found in Kanalku Lake, which is located along the eastern shoreline adjacent to the mouth of the inlet stream (Figure 3). No other spawning areas have been observed in Kanalku Lake (Conitz and Burril 2008). Sampling occurred on 30 August, 5 September, 10 September, and 15 September, 2011. An opercular punch was applied to all sockeye salmon in these samples to prevent double sampling on that day or on subsequent sampling days.

We used Stratified Population Analysis System (SPAS) software (Arnason et al. 1996; http://www.cs.umanitoba.ca/~popan/) to analyze mark-recapture data. SPAS was designed for analysis of two-sample mark-recapture data where Event 1 (marking) and Event 2 (mark-recovery) samples are collected over a number of strata. This software was used to calculate the maximum likelihood Darroch and pooled-Petersen (Chapman's modified) estimates and their standard errors. We evaluated the validity of full pooling of marking and mark-recovery data

(pooled-Petersen estimate) by using the first two chi-square tests provided in the output. These tests provided a reasonable indication of serious violation of the basic mark-recapture assumptions by evaluating 1) complete mixing of marked fish between release (Event 1) and recovery (Event 2) strata, and 2) equal proportions of fish recovered from each marking stratum. A test statistic with $P < 0.05$ was considered "significant," but serious bias was indicated in the pooled-Petersen estimate only if both test statistics were significant. If neither test statistic, or only one of them, was significant, we accepted the pooled-Petersen estimate. Otherwise, we evaluated the stratified Darroch estimate and attempted to find a reasonable partial pooling scheme in order to reduce the number of parameters that needed to be estimated. We used two additional goodness-of-fit tests for the Darroch estimate provided in the SPAS software, along with the guidelines and suggestions in Arnason et al. (1996) and Schwarz and Taylor (1998), in evaluating the estimate and partial pooling schemes. We deemed the weir count of sockeye salmon to be "verified" if the count fell within the 95% confidence interval of the mark-recapture estimate.

If we used a pooled-Petersen estimate, a parametric bootstrap procedure was used to estimate the standard error and construct the 95% confidence interval for the escapement estimate. We assumed that the number of marked fish recaptured in Event 2 (r), follows a hypergeometric probability distribution. Then we used the number of fish marked in Event 1 (m), the number of fish caught in Event 2 (c), and the Petersen estimate of escapement, $\hat{N}$, to generate 5,000 simulated recapture numbers based on the hypergeometric probability density function, $f(r | m, c, \hat{N})$. From the bootstrap values of r, we derived 5,000 Petersen escapement estimates, then calculated the standard error of these estimates and used the 0.025 and 0.975 quantiles to form the 95% confidence interval.

To further test the assumption that fish of different sizes were captured with equal probability during sampling Event 1 (marking) and sampling Event 2 (recovery), we compared the length distributions of fish for groups of fish marked at the weir (m), fish captured on the spawning grounds (c), and marked fish recaptured (r) on the spawning grounds using the Kolmogorov-Smirnov (K-S) two-sample test (Conover 1999; Appendix B). The test hypothesis for each comparison was that there were no differences in the length of fish between the data sets being tested ($P < 0.05$). Similarly, we conducted two chi-square consistency tests to check for gender-selective sampling, with the test hypothesis that there were no differences in the ratio of males to females between the data sets being tested ($P < 0.05$). Gear selectivity in Event 1 was examined by comparing the number of fish of each gender marked in Event 1, and the number of fish of each gender sampled for marks in Event 2. Sampling bias in Event 2 was examined by comparing the number of fish of each gender marked in Event 1 and recaptured during Event 2, to the number of each gender that were marked but not recaptured.

ADULT POPULATION AGE AND SIZE COMPOSITION

The age composition of sockeye salmon at Kanalku Lake was to be determined from a minimum sample of 500 fish collected from live fish at the weir, depending on the run strength. Based on the work by Thompson (1992), and assuming a run of around 1,000 sockeye salmon, a sample of 390 fish was determined to be the size needed to ensure the estimated proportions of each age class would be within 5% of the true value 95% of the time. We increased our sampling goal to 500 fish for the season to ensure we met the target sample size even if 15% of the scale samples were unreadable. We began the season with a weekly sampling goal of 30% of the cumulative weekly escapement. Weekly sampling goals were adjusted by the project leader depending on

inseason run strength. We attempted to sample all sockeye salmon to be marked for the mark-recapture study to minimize fish handling. If a fish appeared overly stressed after marking, or if the handling time exceeded 30 seconds out of the water, the fish was released without additional sampling. The length of each fish was measured from mid eye to tail fork, to the nearest millimeter (mm). Sex was determined by length and shape of the kype or jaw. Three scales were taken from the preferred area of each fish (INPFC 1963), mounted on a gum-card, and prepared for analysis as described by Clutter and Whitesel (1956).

Scale samples were analyzed at the ADF&G salmon aging laboratory in Douglas, Alaska. Age classes were designated by the European aging system where freshwater and saltwater years are separated by a period (e.g., 1.3 denotes a five-year-old fish with one freshwater and three ocean years; Koo 1962). We estimated multiple age-class proportions and means, together with estimates for their standard errors, as described by Thompson (1992) and Cochran (1977). The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week were calculated using equations from Cochran (1977; Appendix C).

RESULTS

SOCKEYE SALMON ESCAPEMENT ESTIMATE

Weir Count

The crew at Kanalku Lake passed a total of 728 adult sockeye salmon through the weir between 25 June and 29 August (Figure 4, Appendix C). No jack sockeye salmon or other species of salmon were observed. No high water events or flooding occurred, and no holes were found in the weir that would have allowed fish to pass uncounted. Daily escapements of sockeye salmon were greatest between 20 July and 17 August. Peak daily escapement occurred on 15 August when 94 sockeye salmon were passed through the weir.
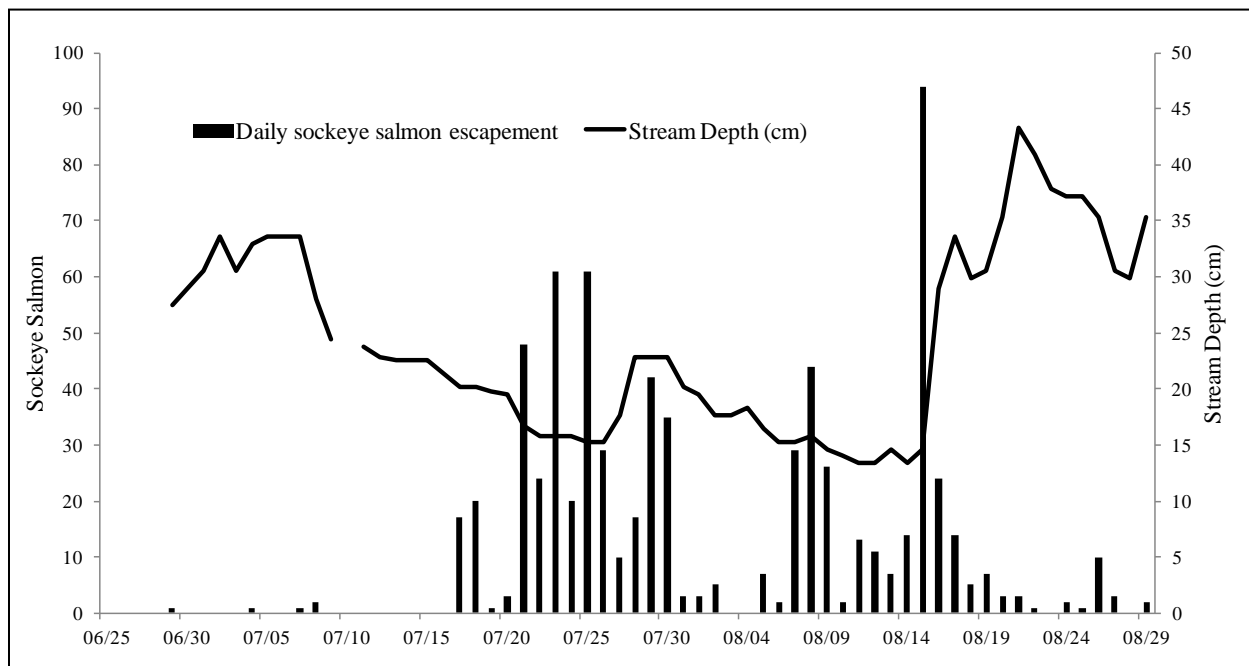

Figure 4.–Daily sockeye salmon escapement and stream depth (cm), Kanalku Lake, 2011.

Weir to Spawning Grounds Mark Recapture

The sampling crew marked a total of 287 adult sockeye salmon at the weir: 72 with left axillary process clips 25 June–23 July, 123 with right axillary process clips 24 July–8 August, and 92 with dorsal fin clips 9–28 August. Recapture efforts were conducted on the spawning grounds in Kanalku Lake on 30 August, 5 September, 10 September, and 15 September. During the recapture events, 223 adult sockeye salmon were captured with a beach seine, of which 93 were weir-marked recaptures (Table 1). The result of the chi-square test of complete mixing of marked fish between the marking (Event 1) and recovery (Event 2) events was significant ($\chi^2 = 13.8$, $P < 0.05$, df = 2). However, the result of the test for equal proportions of marked fish on the spawning grounds was not significant ($\chi^2 = 3.37$, $P = 0.34$, df = 3). A non-significant result for one of these diagnostic tests indicated the pooled estimator was appropriate for estimating abundance in this study. Therefore, we pooled the data and calculated a Petersen estimate of 690 (SE = 46) adult sockeye salmon, with a 95% confidence interval of approximately 600 to 800 fish. The coefficient of variation of 6.7% met our objective of an estimate with a coefficient of variation of less than 15%. Since the weir count of 728 sockeye salmon fit within the 95% confidence intervals of the mark-recapture estimate, we used the weir estimate as our best estimate of escapement in 2011.

Table 1.–Number of sockeye salmon marked at the weir, number sampled for marks, and number recaptured at the Kanalku Lake spawning area in 2011 by marking stratum.

Marking stratum end date	Number marked at weir	Count at weir	Marks recovered by sampling date				Total marks recovered	Proportion of marks recovered
			30-Aug	5-Sep	10-Sep	15-Sep		
23-Jul	72	179	6	12	13	5	36	0.50
8-Aug	123	307	0	10	6	15	31	0.25
28-Aug	92	242	0	6	8	12	26	0.29
Total	287	728	6	28	27	32	93	0.32
Total fish sampled			11	75	72	65	223	
Proportion marked in samples			0.55	0.37	0.38	0.49	0.42	

No size selectivity was detected for Event 1; there was no significant size difference between all fish sampled (*c*) during Event 2 and fish marked in Event 1 and recaptured (*r*) during Event 2 (D = 0.19, *P* = 0.99; Appendix B). There was a significant difference in the size of fish marked (*m*) during Event 1 and the size of marked fish that were recaptured (*r*) during Event 2 (D = 0.19, *P* =0.01; Appendix B). Fish were smaller in Event 2 than in Event 1 (Appendix B). These results suggest a case *II* situation (Appendix B), and further suggest abundance can be estimated using a pooled-Petersen model from the entire data set without stratification.

We determined that no gender-related gear selectivity occurred during Event 1: the test for equal proportions of males and females marked in Event 1 and sampled in Event 2 was not significant ($\chi^2 = 3.82$, $P = 0.05$, df = 1; Appendix E). There was sampling bias related to gender during Event 2: the test of the frequency of marked males and females recovered compared to those not recovered in Event 2 was significant ($\chi^2 = 4.9$, $P = 0.03$, df = 1).

ADULT POPULATION AGE AND SIZE COMPOSITION

The Kanalku Lake crew sampled 233 adult sockeye salmon for age, sex, and length composition in 2011, of which 201 were successfully aged. The sockeye salmon sampled were found to be

predominately age-1.2 fish (49.4%) and 1.3 fish (46.0%). Only a small proportion of the fish sampled were found to have spent more than one year in their freshwater environment (Table 2). Age-1.2 fish had a mean length of 522 mm for males and 501 mm for females and age-1.3 fish had a mean length of 566 mm for males and 508 mm for females (Table 3).

Table 2.–Estimated age composition of the 2011 sockeye salmon escapement at Kanalku Lake based on scale samples, weighted by statistical week.

Brood Year	2007	2006	2006	2005	
Age	1.2	1.3	2.2	2.3	Total
Sample Size	105	86	9	1	201
Escapement by age class	360	335	30	3	728
SE of escapement	20	19	8	3	
Percent	49%	46%	4%	0%	
SE of percent	3%	3%	1%	0%	

Table 3.–Length composition of the 2011 sockeye salmon escapement at Kanalku Lake, weighted by statistical week.

Brood Year	2007	2006	2006	2005	
Age	1.2	1.3	2.2	2.3	Total
Male					
Sample size	41	74	1	1	117
Mean length (mm)	522	566	550	565	
SE	4	2			
Female					
Sample size	64	12	8	0	84
Mean length (mm)	501	549	508		
SE	3	5	9		
All Fish					
Sample size	105	86	9	1	201
Mean length (mm)	510	563	512	565	
SE	3	2	9		

DISCUSSION

The weir count of 728 sockeye salmon at Kanalku Lake was considered the most accurate estimate of escapement in 2011, since it fell within the 95% CI of the mark-recapture estimate. Although the weir count was validated by the mark-recapture estimate in 2011, in some years the Kanalku Lake weir counts did not fall within the 95% CI of the mark-recapture estimates of escapement (Vinzant et al. 2010; Vinzant et. al 2011). In 2008 and 2010, the weir counts fell just short of the lower bound of the 95% CI (Figure 5; Appendix A). Although weirs sometimes leak fish, it is difficult to imagine that a large portion of the sockeye salmon run escapes through the Kanalku Lake weir uncounted, given the small size of the weir and stream, narrow "pink salmon" picket spacing in the weir, low water flow, and meticulous weir maintenance. Mark-recapture estimates can be biased in numerous ways; e.g., loss of marks through handling mortality or non-recognition of marks would result in an inflated estimate (Schwarz and Taylor 1998). Stress and injury incurred from scaling the partial barrier falls and subsequent handling at the weir may account for some of the discrepancy (i.e., loss of marked fish), but it has been

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difficult to explain the reason for the differences between the weir counts and mark-recapture estimates at Kanalku Lake.

The 2011 escapement was below the average escapement of 1,300 sockeye salmon from 2001 to 2010. However, we did not expect a large run of sockeye salmon in 2011 due to the small parent-year escapement of only 461 sockeye salmon in 2007 (Figure 5; Appendix A). Kanalku Lake sockeye salmon return primarily as age 1.2 fish, and annual escapements are typically composed largely of that age class (Table 4). The age composition of the sockeye salmon escapement in 2011, however, was about evenly split between age-1.2 (49.4%) and age-1.3 (46.0%) fish (Table 2). The high proportion of age-1.3 fish in the escapement was the result of a small return of age-1.2 fish from the poor 2007 parent year.

In 2011, we conducted a study to look for size differences between fish measured at the weir and on the spawning grounds during the mark-recapture efforts which might indicate bias in the mark-recapture estimate or the weir count (Appendix D). The results of the K-S tests for the evaluation of Event 2 suggested there was a difference in the size of fish marked at the weir (m) and recaptured on the spawning grounds (r). For the evaluation of Event 1, however, we failed to detect any difference in size between fish captured on the spawning grounds (c) and marked fish recaptured on the spawning grounds (r). If there had been size selectivity at the weir, we would expect to see a difference in size between marked and unmarked fish captured on the spawning grounds. We conclude that our sample at the weir was unbiased but there was gear selectivity in our spawning grounds sample. Fish captured with a beach seine on the spawning grounds during Event 2 were smaller than the fish sampled at the weir during Event 1. The average size difference was small: 13mm for females and 22mm for males. In addition, we recaptured twice as many marked males (61) as females (32) on the spawning grounds, which further suggests gear selectivity. Our weir count was essentially the same as the mark-recapture estimate in 2011, but it is possible that gear selectivity on the spawning grounds contributed to the difference in other years.
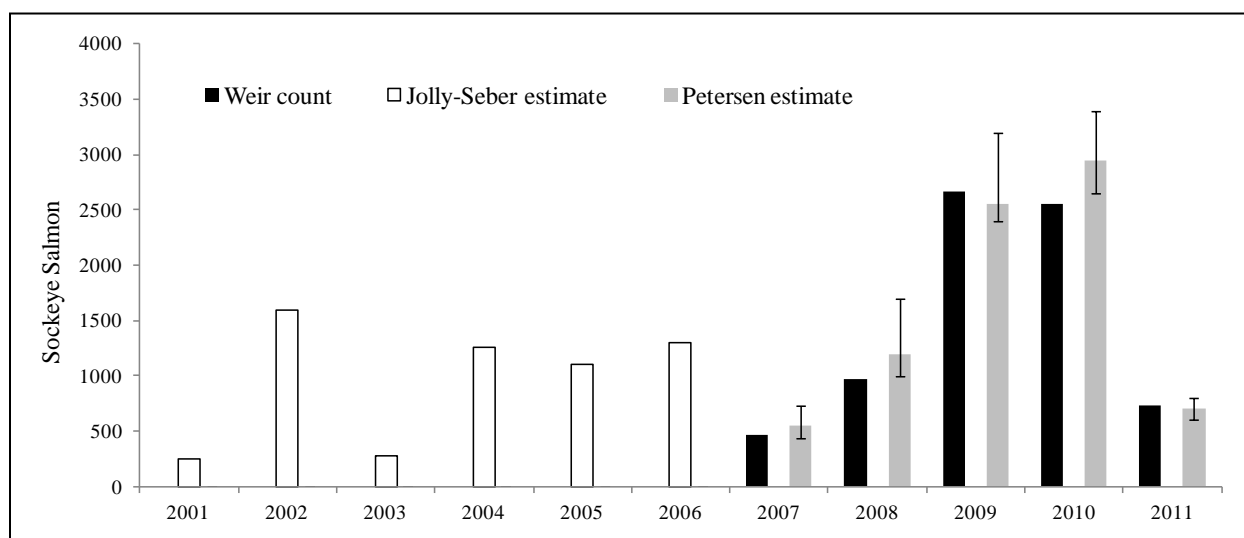
Figure 5.–Estimated adult sockeye salmon escapements from 2001 to 2011. Error bars represent the 95% confidence intervals of the Petersen mark-recapture estimates.

Table 4.–Proportions of aged sockeye salmon sampled at Kanalku Lake from 2001 to 2011.

Year	1.1	1.2	1.3	2.1	2.2	2.3	Age 1.-	Age 2.-
2001	0.00	0.54	0.44	0.00	0.02	0.00	0.98	0.02
2002	0.00	0.80	0.16	0.00	0.03	0.00	0.97	0.03
2003	0.00	0.87	0.12	0.00	0.01	0.00	0.99	0.01
2004	0.00	0.76	0.23	0.00	0.01	0.00	0.99	0.01
2005	0.00	0.85	0.11	0.01	0.03	0.00	0.96	0.04
2006	0.00	0.97	0.03	0.00	0.00	0.00	1.00	0.00
2007	0.00	0.37	0.54	0.00	0.08	0.01	0.91	0.09
2008	0.00	0.96	0.02	0.00	0.03	0.00	0.97	0.03
2009	0.00	0.57	0.37	0.00	0.06	0.00	0.94	0.06
2010	0.00	0.87	0.12	0.00	0.01	0.00	0.99	0.01
2011	0.00	0.52	0.43	0.00	0.04	0.00	0.95	0.05
Mean	0.00	0.77	0.20	0.00	0.03	0.00	0.97	0.03
SE	0.00	0.74	0.23	0.00	0.03	0.00	0.97	0.03

The size of the spawning population at Kanalku Lake is also determined by the number of fish that are able to ascend Kanalku falls. In previous years, we have suggested that low water flow favors sockeye salmon passage over the partial barrier falls at Kanalku Creek (Vinzant et al. 2010; Vinzant and Bednarski 2010; Vinzant et al. 2011). Compared to previous years, the mean stream depth during the 2011 season was low throughout the peak period of sockeye salmon migration (15 July to 10 August; Figure 6). Although we observed a much smaller escapement of sockeye salmon in 2011, it did not appear that water flow at the falls was a major factor in the lower escapement.
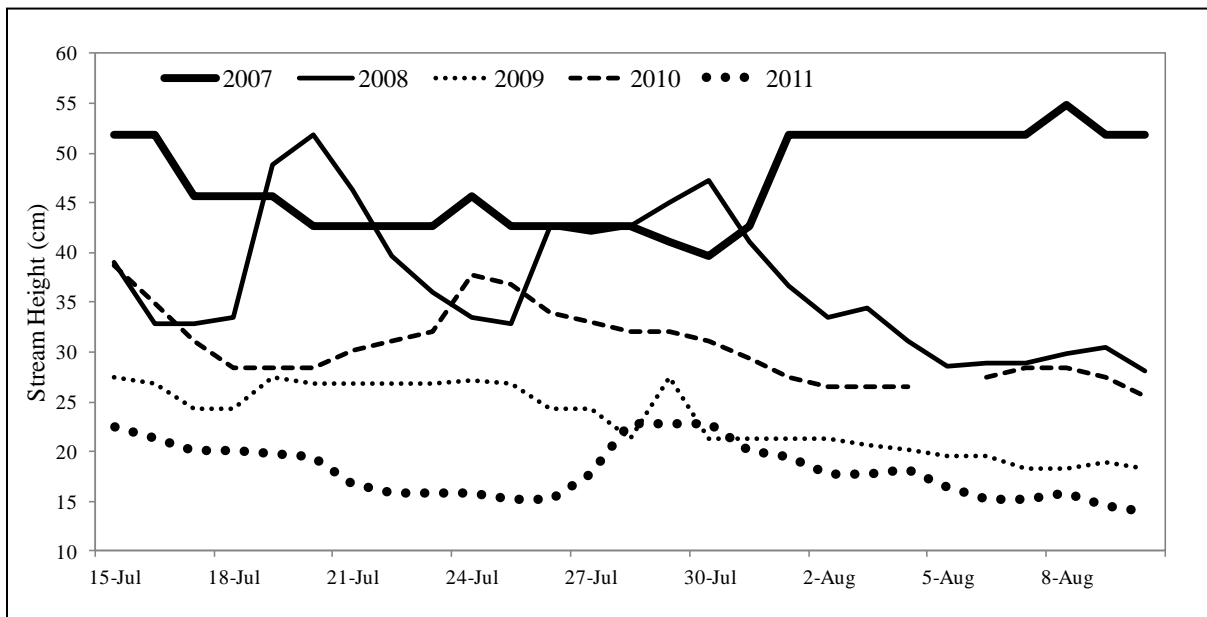
Figure 6.–Approximate daily stream depth at Kanalku Lake weir during the peak of sockeye salmon migration (15 July–10 August), 2007–2011.

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APPENDIX A: KANALKU LAKE ANNUAL ESTIMATED SOCKEYE SALMON ESCAPEMENT AND HARVEST 2001–2011

Appendix A1.–Kanalku Lake annual estimated sockeye salmon escapement and harvest 2001–2011. Estimates were based on weir and mark-recapture estimates. The best annual estimate is in bold. Subsistence harvest is reported from subsistence salmon fishing permits. There was a voluntary subsistence closure from 2002 to 2006.

Year	Weir	Mark-recapture	SE	95% Lower CI	95% Upper CI	Harvest
2001		**250**		130	380	951
2002		**1,600**		1,200	1,400	14
2003		**280**		250	300	90
2004		**1,250**		–	–	60
2005		**1,100**		900	1,000	50
2006		**1,300**		1,000	1,200	51
2007	**461**	576		430	740	10
2008	967	**1,200**	119	1,000	1,500	708
2009	**2,664**	2,540	165	2,500	3,200	600
2010	2555	**2,970**	182	2,660	3,380	571
2011	**728**	690	46	600	800	419

APPENDIX B: DETECTION OF SIZE AND/OR SEX SELECTIVE SAMPLING

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (chi^2 test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M and R, C and R, and M and C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**

Case I:

Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test will likely detect small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R *P*-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

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C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R *P*-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R *P*-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \, \hat{p}_{ik} \; ; \text{and,} \tag{1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right). \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

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Results of the Kolmogorov-Smirnov test statistics for analysis of size-selective sampling of sockeye salmon at Kanalku Lake, 2011, suggest a *Case II* situation.

Event Evaluation	Hypothesis Test	Sample Size (n)	D Statistic	*P* Value	Result
Event 1	There is no size difference between all fish captured (c) in Event 2, and marked fish recaptured (r) in Event 2.	c(223) r(93)	0.05	0.99	Not rejected
Event 2	There is no size difference between fish marked (m) in Event 1, and marked fish recaptured (r) in Event 2.	m(233) r(93)	0.19	0.01	Rejected

APPENDIX C: ESCAPEMENT SAMPLING DATA ANALYSIS

The weekly age-sex distribution, the seasonal age-sex distribution weighted by week, and the mean length by age and sex weighted by week, for smolt and adults, were calculated using equations from Cochran (1977; pages 52, 107–108, and 142–144).

Let

h	$=$	index of the stratum (week),
j	$=$	index of the age class,
p_{hj}	$=$	proportion of the sample taken during stratum h that is age j,
n_h	$=$	number of fish sampled in week h, and
n_{hj}	$=$	number observed in class j, week h.

Then the age distribution was estimated for each week of the escapement in the usual manner:

$$\hat{p}_{hj} = n_{hj}/n_h \; . \tag{1}$$

If N_h equals the number of fish in the escapement in week h, standard errors of the weekly age class proportions are calculated in the usual manner (Cochran 1977, page 52):

$$SE(\hat{p}_{hj}) = \sqrt{\left[\frac{(\hat{p}_{hj})(1-\hat{p}_{hj})}{n_h - 1}\right]\left[1 - n_h/N_h\right]}. \tag{2}$$

The age distributions for the total escapement were estimated as a weighted sum (by stratum size) of the weekly proportions. That is,

$$\hat{p}_j = \sum_h p_{hj}(N_h/N), \tag{3}$$

such that N equals the total escapement. The standard error of a seasonal proportion is the square root of the weighted sum of the weekly variances (Cochran 1977, pages 107–108):

$$SE(\hat{p}_j) = \sqrt{\sum_j^h [SE(\hat{p}_{hj})]^2 (N_h/N)^2} \; . \tag{4}$$

The mean length, by sex and age class (weighted by week of escapement), and the variance of the weighted mean length, were calculated using the following equations from Cochran (1977, pages 142–144) for estimating means over subpopulations. That is, let i equal the index of the individual fish in the age-sex class j, and y_{hij} equal the length of the ith fish in class j, week h, so that,

$$\hat{\bar{Y}}_j = \frac{\sum_h (N_h/n_h)\sum_i y_{hij}}{\sum_h (N_h/n_h)n_{hj}} \; , \text{ and} \tag{5}$$

$$\hat{V}\left(\hat{\bar{Y}}_j\right) = \frac{1}{\hat{N}_j^2}\sum_h \frac{N_h^2(1-n_h/N_h)}{n_h(n_h-1)}\left[\sum_i (y_{hij} - \bar{y}_{hj})^2 + n_{hj}\left(1 - \frac{n_{hj}}{n_h}\right)\left(\bar{y}_{hj} - \hat{\bar{Y}}_j\right)^2\right].$$

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APPENDIX D: DAILY AND CUMULATIVE COUNTS OF SOCKEYE SALMON, WATER DEPTH, AND TEMPERATURE AT KANALKU LAKE IN 2011

Appendix D1.–Daily and cumulative counts of sockeye salmon, water depth, and temperature at Kanalku Lake in 2011. No other salmon species were observed.

Date	Sockeye salmon		Water depth (m)	Water temperature (°C)	Air temperature (°C)
	Daily	Cumulative			
25–Jun	0	0	0.000		
26–Jun	0	0	0.000		
27–Jun	0	0	0.000		
28–Jun	0	0	0.000		
29–Jun	1	1	0.274	15.0	12.5
30–Jun	0	1	0.290	13	12.5
1–Jul	0	1	0.305	13	11
2–Jul	0	1	0.335	13.0	11.0
3–Jul	0	1	0.305	12.0	11.0
4–Jul	1	2	0.329	13.0	12.5
5–Jul	0	2	0.335	13.0	11.0
6–Jul	0	2	0.335	13.0	11.0
7–Jul	1	3	0.335	13.0	12.0
8–Jul	2	5	0.280	13.0	13.0
9–Jul	0	5	0.244	13.0	13.0
10–Jul	0	5		14.0	17.0
11–Jul	0	5	0.238	13.5	16.0
12–Jul	0	5	0.229	14.0	17.0
13–Jul	0	5	0.226	14.0	15.0
14–Jul	0	5	0.226	14.0	15.5
15–Jul	0	5	0.226	14.0	16.0
16–Jul	0	5	0.213	16.0	15.0
17–Jul	17	22	0.201	17.0	17.0
18–Jul	20	42	0.201	17.0	13.0
19–Jul	1	43	0.198	16.0	12.0
20–Jul	3	46	0.195	16.0	13.0
21–Jul	48	94	0.168	16.0	16.0
22–Jul	24	118	0.158	17.0	17.0
23–Jul	61	179	0.158	17.0	17.0
24–Jul	20	199	0.158	16.5	15.0
25–Jul	61	260	0.152	15.0	12.0
26–Jul	29	289	0.152	15.0	12.0
27–Jul	10	299	0.177	16.0	12.5
28–Jul	17	316	0.229	15.5	13.0
29–Jul	42	358	0.229	16.0	12.5
30–Jul	35	393	0.229	15.5	13.0
31–Jul	3	396	0.201	15.0	12.5
1–Aug	3	399	0.195	15.0	12.5
2–Aug	5	404	0.177	15.0	13.0

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Date	Sockeye salmon		Water depth (m)	Water temperature (^{o}C)	Air temperature (^{o}C)
	Daily	Cumulative			
3–Aug	0	404	0.177	14.5	13.0
4–Aug	0	404	0.183	14.0	12.0
5–Aug	7	411	0.165	15.0	13.0
6–Aug	2	413	0.152	15.0	15.0
7–Aug	29	442	0.152	16.0	14.0
8–Aug	44	486	0.158	16.0	15.0
9–Aug	26	512	0.146	15.0	15.0
10–Aug	2	514	0.140	15.0	13.0
11–Aug	13	527	0.134	16.0	12.5
12–Aug	11	538	0.134	16.0	12.5
13–Aug	7	545	0.146	16.0	13.0
14–Aug	14	559	0.134	15.0	13.5
15–Aug	94	653	0.146	15.0	10.5
16–Aug	24	677	0.290	14.0	12.0
17–Aug	14	691	0.335	15.0	13.0
18–Aug	5	696	0.299	15.0	12.5
19–Aug	7	703	0.305	14.0	12.0
20–Aug	3	706	0.354	13.0	13.5
21–Aug	3	709	0.433	13.0	12.5
22–Aug	1	710	0.408	13.0	13.0
23–Aug	0	710	0.378	13.0	11.0
24–Aug	2	712	0.372	13.0	12.0
25–Aug	1	713	0.372	13.5	13.0
26–Aug	10	723	0.354	13.0	11.0
27–Aug	3	726	0.305	13.0	13.0
28–Aug	0	726	0.299	13.0	13.0
29–Aug	2	728	0.354	13.0	13.0
Season total		728			

APPENDIX E: SAMPLE SIZE OF SOCKEYE SALMON MARKED AT THE WEIR

Appendix E1.–Sample size of sockeye salmon marked at the weir (m), all fish sampled on the spawning grounds (c), and marked fish recovered on the spawning grounds (r), by sex, at Kanalku Lake in 2011.

Sex	Group	Number Sampled
Female	Marked in Event 1 (m)	102
Female	All fish sampled in Event 2 (c)	95
Female	Marked fish recovered in Event 2 (r)	32
Male	Marked in Event 1 (m)	131
Male	All fish sampled in Event 2 (c)	128
Male	Marked fish recovered in Event 2 (r)	61